

Design Course

Virtual Reality: Introduction

An Introduction to Virtual Reality

by

Azif Ismail with Prof. Jayesh S. Pillai

IDC, IIT Bombay

Source:

<https://www.dsource.in/course/virtual-reality-introduction>



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<https://www.dsource.in/course/virtual-reality-introduction/what-virtual-reality>

What is Virtual Reality?

Ability of imagination is one of the profound traits of the human psyche which distinguishes us from other organisms. Our interminable efforts to reimagine the real world should be considered as an instinctive behavioural aspect. How often do we end up indulging ourselves in the virtual realms of daydreams or a fictitious world triggered by literature or similar stimuli? Our mind, the most intuitive Virtual Reality device, seamlessly simulates these explorations which are influenced by the traces of memories developed by virtue of the constant interactions with the real world.

Definition

The term Virtual Reality (VR) is a conjunction of two antonymous words 'virtual' and 'reality', describing the nature of experience which it caters to. VR can be defined as the experience of actually being present in a virtual world with the help of a system which makes us believe that we are in a real world.

Components of VR

• Virtual World:

Virtual World is an alternative realm which is simulated for the user to experience, by a VR system. The components of the virtual world depend on the purpose for which the world is designed. This imaginative space progresses through the ideas of the creator, which is simulated using computer programs. The degree of immersion achieved by a VR experience often depends on the ability of the virtual world to respond to the user's interactions by constantly updating itself.

• Interaction:

The believability of any virtual space to be real depends upon its ability to respond to the user's interactions. When a virtual world is presented to us by a system with immense possibilities of interaction, we tend to react intuitively to the objects, characters and the space itself. The interactions can be in the form of sensory inputs or physical movements with respect to the imaginary space. The computer system which acts as a mediator gathers these inputs, analyses them and updates the virtual world accordingly.

• Hardware:

The hardware comprises of the physical equipment which aids the user to be involved in a VR experience. The head mounted display, cameras, and sensors for position tracking are some of the typical examples of hardware components. The information regarding the user interactions, often in the form of sensory cues is assessed by the hardware and passed on to the computer system (software) which updates the virtual world.

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- **Software:**

Software includes the computational components which are used to render and manipulate the virtual world according to the user's interactions with the system. The effectiveness of a virtual world depends on the computational power of a Graphical Processing Unit which is responsible for rendering the visual representations and adding possibilities of interactions. Another parameter decided by the software is called 'motion to photon latency' which is the time required for the virtual world to update according to the head movement (perspective shift) or other sensory interactions. A higher value of this latency can cause adverse effects like motion sickness and nausea.

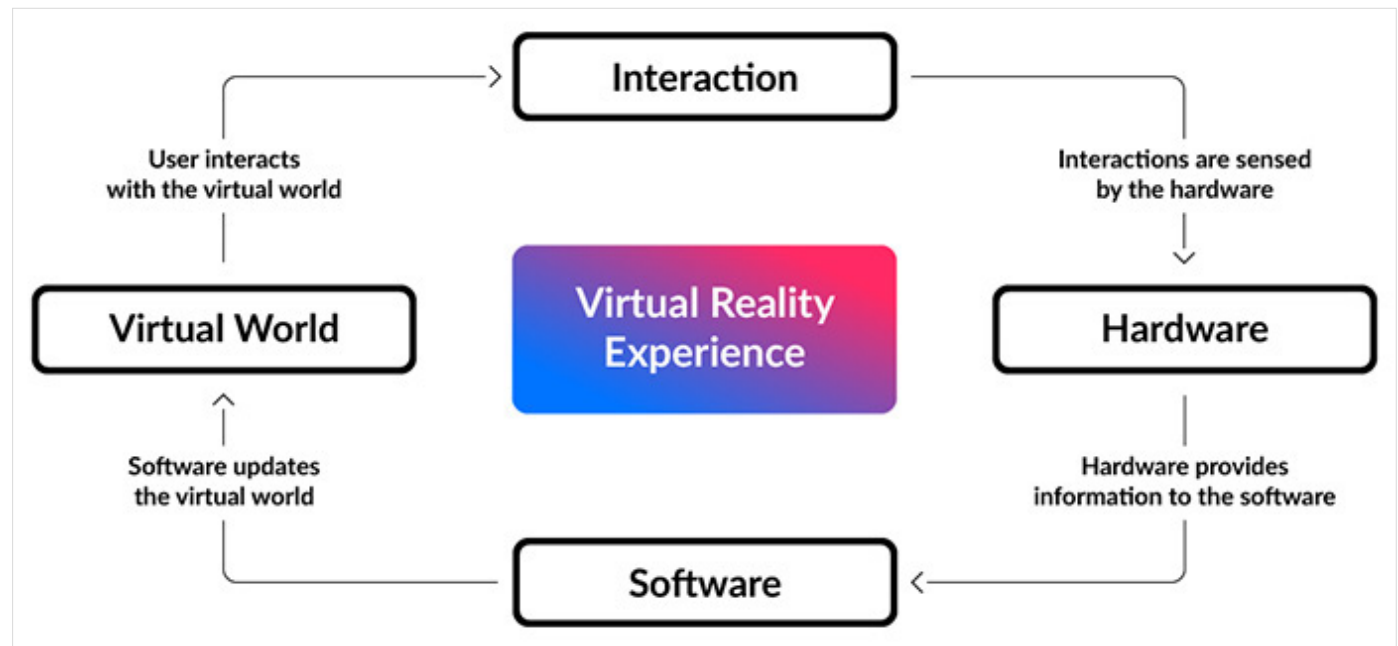


Fig 1. An overview of a VR System

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Related Technologies

The definitions and explanations of VR and its derivatives are always prone to iterations because of the evolving nature of the domain. In 1994, Paul Milgram and Fumio Kishino defined a spectral representation of experiences related to VR called Reality-Virtuality **Continuum** [1]. The spectrum exists between the ideal extremes of a completely virtual world and real world keeping the augmented versions of these in between.

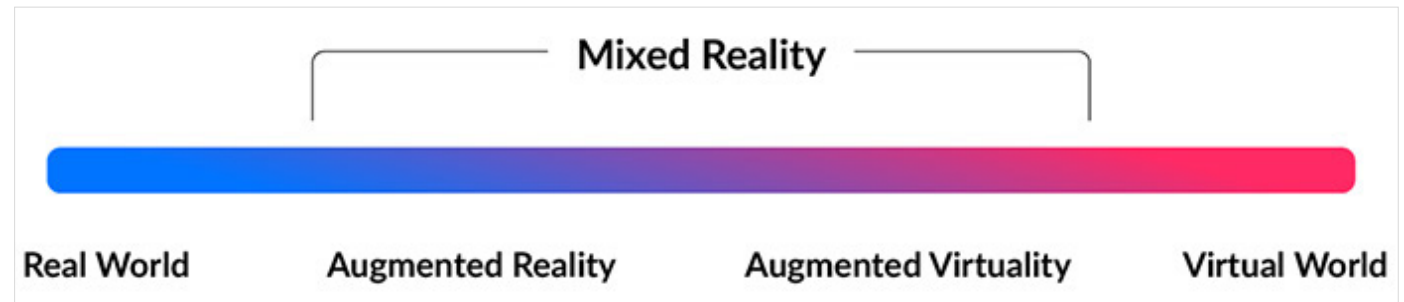


Fig 2. Adopted from Reality-Virtuality Continuum [1]

- **Mixed Reality:**

The conventional definition of a VR experience refers to when the user is immersed in a completely synthetic world with the help of a system. As the technology progressed to cater to different applications, a subclass of experiences related to VR came into existence which required combinations of real and virtual world possibilities. Mixed Reality can be considered as a range of experiences existing between the completely virtual or real extremes of the spectrum. The derivatives of Mixed reality can be augmented forms of the real world by virtual elements (Augmented Reality) or augmented forms of the virtual world by real elements (Augmented Virtuality).

- **Augmented Reality:**

Augmented Reality can be defined as the experience of actually being present in a real world which is enriched by the virtual entities which are augmented on it with the help of a system. On contrary to the VR experience, here, the reality itself is modified by integrating desired virtual elements into it which opens up various possibilities of interaction.

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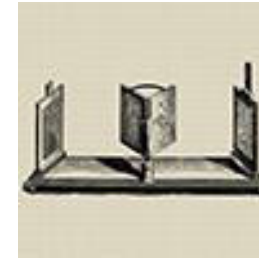
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Evolution of VR



Communication Media



Stereoscopy



First Flight Simulator



Cinerama



Sensorama Simulator



Telesphere Mask



The Sword of Damocles - Head Mounted Display



LEEP Display

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Visual Programming Lab Research (VPL)



Virtuality Gaming System



Cave Automatic Virtual Environment



SEGA VR Goggles



Nintendo Virtual Boy



Oculus Rift



Google Cardboard



HTC Vive

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360 Video



Standalone VR Headsets

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Communication Media

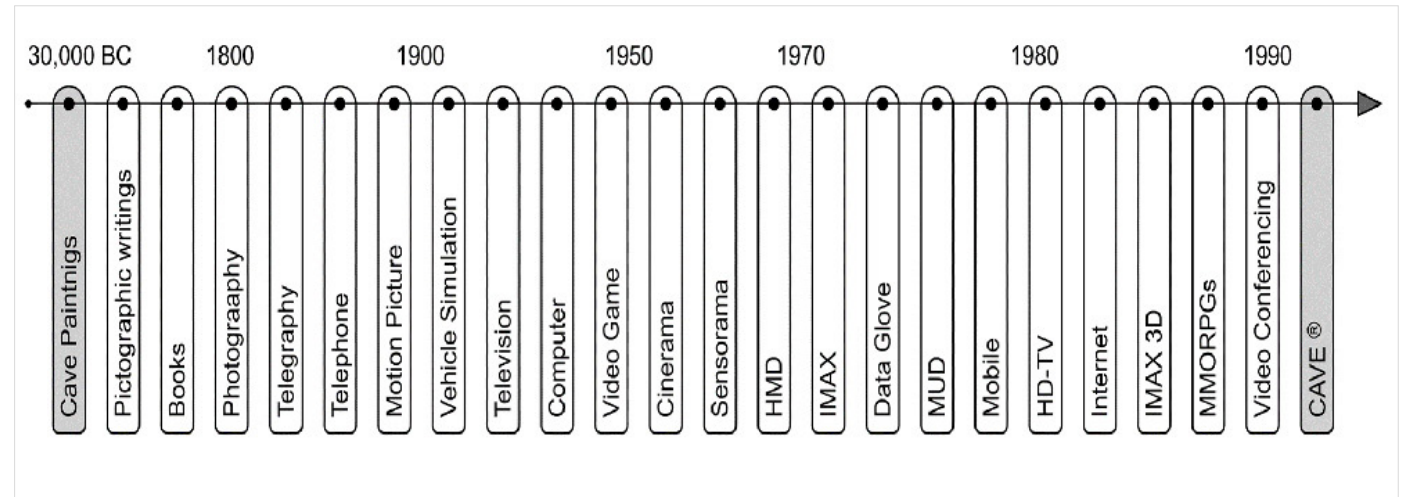


Fig 1. Timeline for Evolution of Communication Media [2]

Image Source: Article - Evoked Reality

1. The Era of Paintings

The evidence for the endless quest of humanity to abstract information available from the real world and to reproduce it as visual explorations can be traced back to the prehistoric era. Cave paintings can be considered as the initial efforts of human beings to recreate the physical world around them and represent them in a virtual form, with the help of very basic resources that were readily available around them. The most common elements depicted in these paintings comprised of animal figures, human figures or parts of human forms, and abstract form explorations of geometric shapes or signs. The visual explorations can be considered as forerunners of communication media or even art, which helped humans to escape the rigidity of real world and explore other iterations of reality itself.

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Fig 2. Photograph of animal painting in Chauvet Cave, France

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The Greek classical paintings (5th to 4th century BC) characterized by heroic realism, reflected the anatomy of the human body exactly as seen in the real world. This marked an advancement towards incorporating realism into paintings. In Europe (12th to 13th century AD), artists started using the medium of Frescoes to decorate the interior of churches. The round wall inside churches was decorated with long strips of paintings, depicting the life and miracles of Christ and other saints for the purpose of edification. Another noteworthy example is that of The Sistine Chapel ceiling painted by Michelangelo in the early 16th century. This renowned artwork of renaissance era enriched the interior of the church with depictions from the holy book of Genesis. The mesmerizing form and aesthetics of these artworks often provoked the viewers to transform themselves into a spiritual realm, which, by its true nature is experiencing VR itself.



Fig 3. The Sistine Chapel Ceiling

Image Source

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2. Photography

In 1826, Nicéphore Niépce conducted an experiment with camera obscura fitted with photosensitive plates which resulted in the development of first photographic image known to the mankind. The experiment was named as heliography by himself.

Louis Daguerre, a theater screen painter from France, worked with Niépce for further development of the technology and to reduce the technical hindrances like long exposure time. In 1838, Daguerre became successful in developing a photographic image of the street view from the window of his studio. This image is considered as the first photograph to feature people in it.



Fig 4. Boulevard du Temple, a Daguerreotype made by Louis Daguerre in 1838

Image Source

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The press started using photography as Daguerreotype went on to gain popularity. The ability of photographs to simulate the realistic images in utmost proximity opened up new dimensions for documenting real life scenarios. During the breakage of the Civil War in the United States, Mathew B Brady along with his crew of 20 photographers started a campaign to photograph the hostilities of war. The incredible record thus produced was showcased to the public. The truthful depictions of agony created a powerful impact on the viewers as if they were experiencing the ironies of war through these frames or windows.



Fig 5. Civil War as Photographed by Mathew B Brady

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3. Motion Picture

In 1879, an American photographer Eadweard Muybridge conducted an interesting experiment on spontaneous photography. Muybridge arranged a setup of 12 cameras in series, along a race track with threads across to operate the shutters of the cameras. Through this experiment which produced instantaneous photographs in a sequence exposing the racehorse in its gallop. Later, when he copied silhouettes of these images into a rotatable disc, it induced an illusion of motion through sequential movement of these still images. Though the concept of moving images was exploited earlier in the form of devices like Phenakistoscope and Zoetrope, Muybridge's experiment stands significant in leading light to further developments of motion pictures.

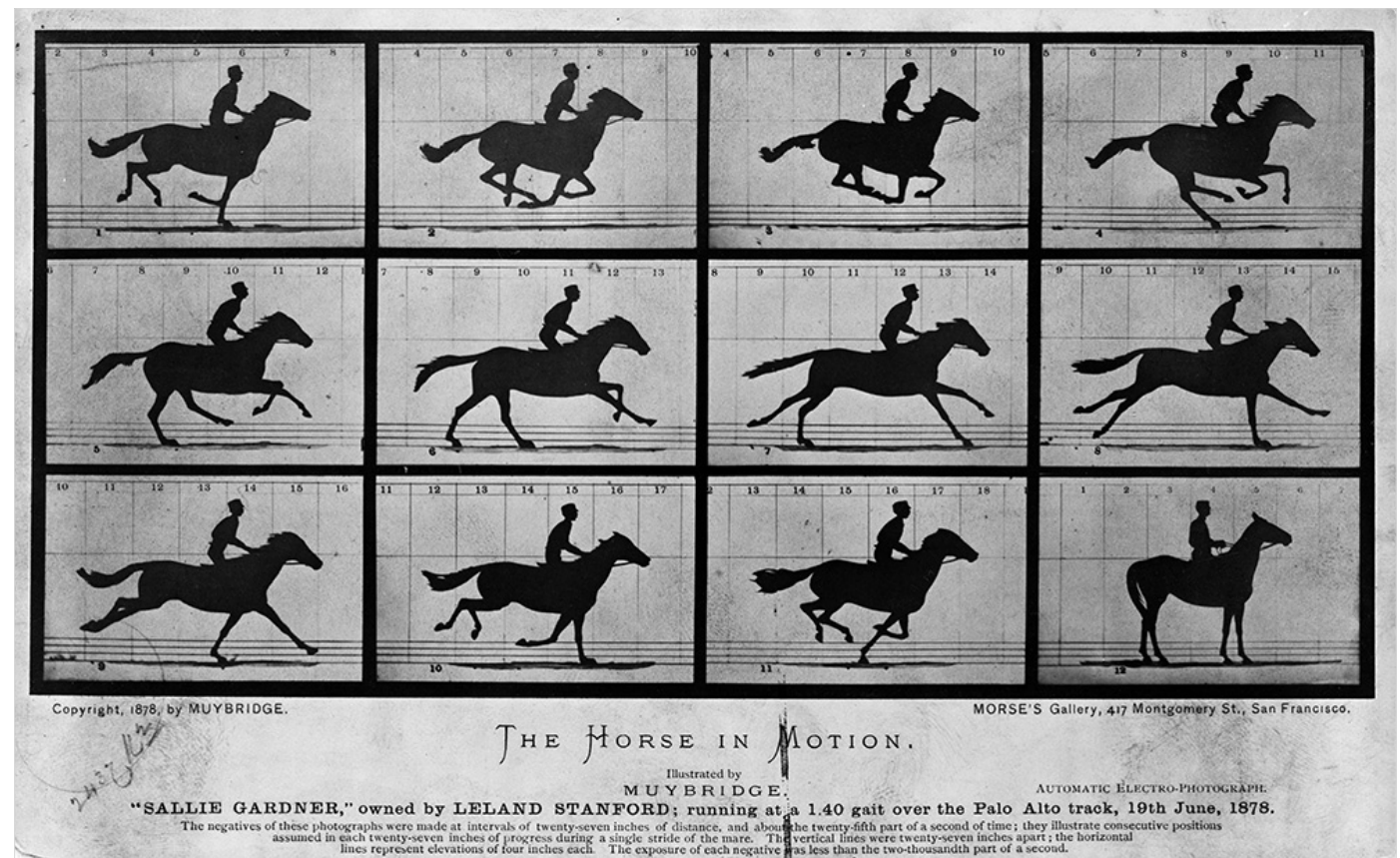


Fig 6. The Horse in Motion by Eadweard Muybridge

Image Source

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In 1895, Auguste Lumière and Louis Lumière invented an instrument named Cinematograph, which could record, print and project moving images. The relatively light and hence portable instrument made it possible to record images outside a studio setup. The first recorded footage was an outdoor shot showing some workers leaving the Lumière factory. The initial public screening of Lumière's films was held at the Grand Café in Paris including ten short films recorded and projected by the Cinematograph including Workers Leaving the Factory and L'Arrivée d'un Train en Gare de La Ciotat (The Arrival of a Train at La Ciotat Station). A popular myth revolving around the screening is that the spectators were undergoing a state of panic, deceived by the images of the onrushing locomotive which appeared to come out of the screen. The ability of moving pictures to capture and show life as it creates an unimaginable sense of reality in the viewers. The viewers succumbed themselves to the overwhelming realism suggested by the camera, unable to distinguish between the reel and real.



Fig 7. The Arrival of a Train at La Ciotat Station

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Stereoscopy

Human vision or the way in which we visually perceive things is a complex process. Our brain acts much like a sensor for the photographic lens to process the information gathered by the eyes to formulate the visual imagery. During the process, the brain uses different kinds of visual cues (perspective, scale, overlapping of objects), to assess the relative distance of the object from the viewer and its dimensional depth. The disparity in perspective between objects seen separately through left and right eye is the paramount feature that creates an illusion of depth. Stereoscopy is the process by which an illusion of depth is created in a flat image (photograph or a painting), by presenting slightly different images to the left and right eyes, making the experience similar to how we see things in reality.

1. Wheatstone Stereoscope

In 1828, Sir Charles Wheatstone invented the earliest type of stereoscopes which consisted of a pair of mirrors, each set at an angle of 45 degrees to the viewer's eyes, reflecting two slightly different images for the left and right.

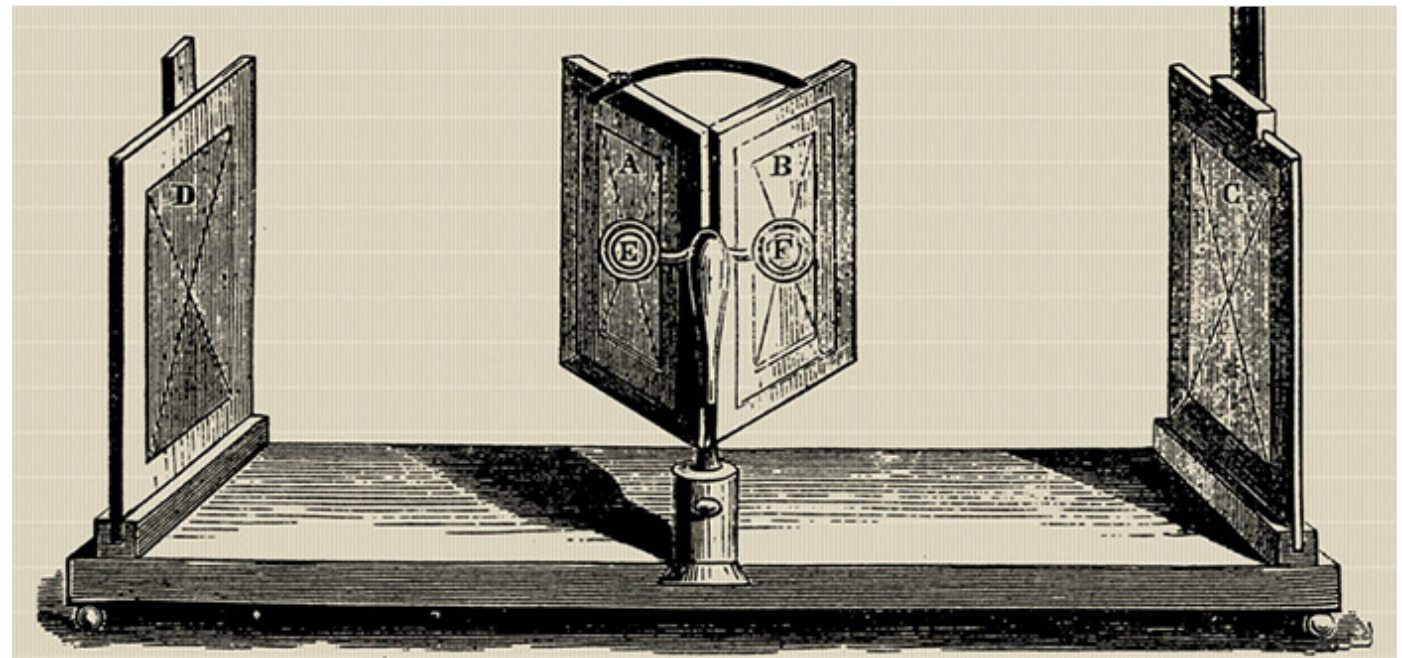


Fig 1. Charles Wheatstone Mirror Stereoscope

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2. Brewster Lenticular Stereoscope

David Brewster implemented the idea of using lenses to view dissimilar images as one creating the illusion of depth. The relatively smaller, handheld lenticular stereoscope thus developed came to be known as Brewster Stereoscope.



Fig 2. Brewster Lenticular Stereoscope

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First Flight Simulator

In 1929, Edward Link developed the first flight simulator for providing enough hands on experience for the pilots under controlled environments (interiors). The 'Link Trainer' consisted of a stationary flight replica with a motion actuating platform which replicated the actual movement patterns for the trainees.



Fig 1. Link Trainer Flight Simulator

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Cinerama

Cinerama, invented by Fred Waller, was a process intended to achieve widescreen cinematic experience by deploying multiple projectors which simultaneously project the images on a huge curved screen. The photographic unit of the same consisted of three cameras, each recording one-third of the desired image. The cameras were mounted as a single unit arranged in a crisscross pattern similar to that of the projection system. The first Cinerama projection was conducted in 1952 with a film titled 'This is Cinerama'.



Fig 1. A Still from 'This is Cinerama' Screening
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Sensorama Simulator

Sensorama is a multi-sensory simulator system developed by Morton Heilig to provide an immersive cinematic experience. The objective of the invention was to encourage the participatory experience of the viewer by enhancing the stereoscopic moving images with auditory, aromatic and haptic feedback [3].



Fig 1. Sensorama Simulator

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Telesphere Mask

In 1960, Morton Heilig developed a stereoscopic television apparatus aimed for individual use in a portable form factor which could be attached to the user's head. The Telesphere mask comprised of optical units, television tube units, earphones, and discharge nozzles designed as a personalized device which could be adjusted to the individual's **comfort** [4].



*Fig 1. Telesphere Mask Demonstration
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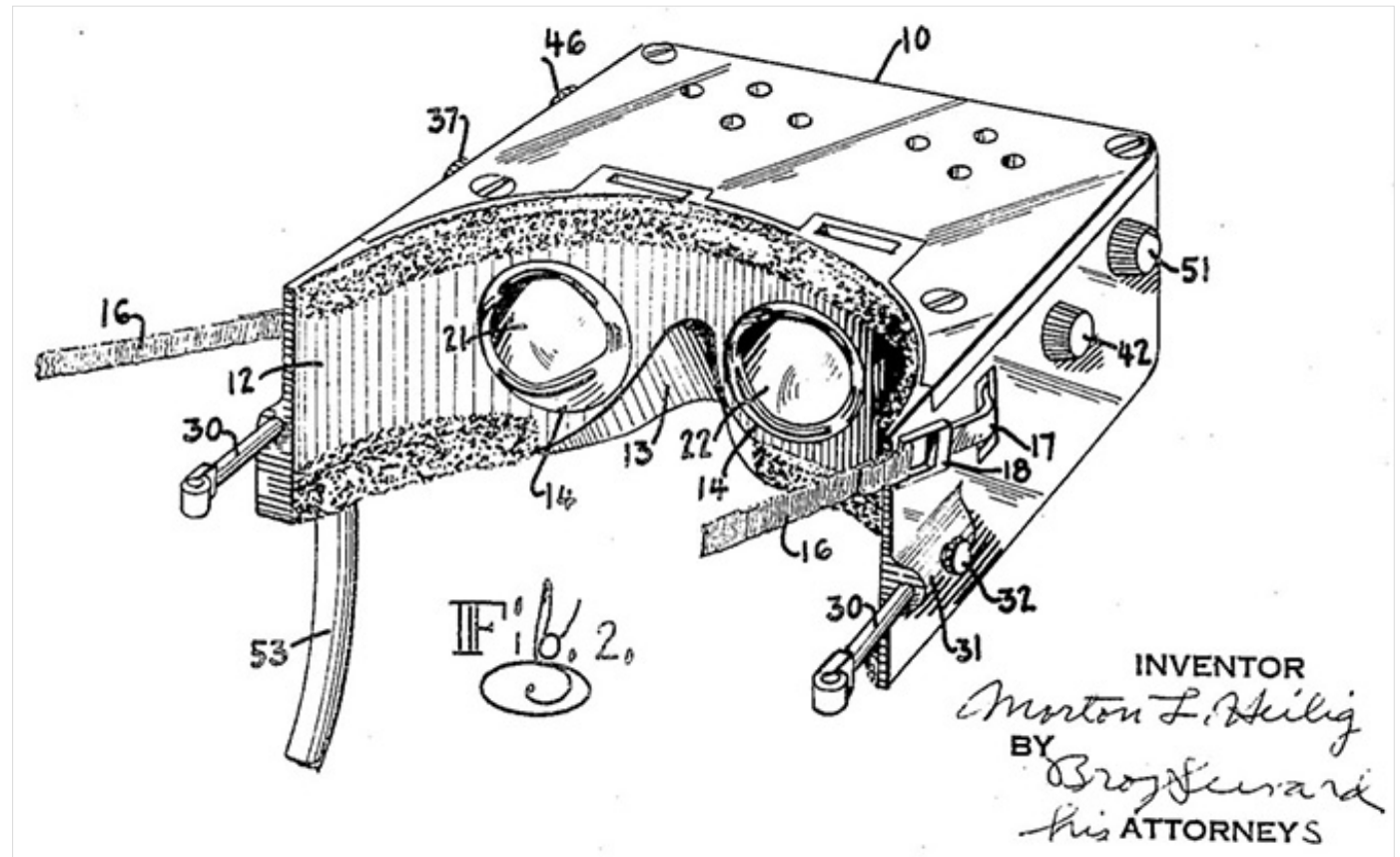
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The Sword of Damocles - Head Mounted Display

In 1963, Ivan Sutherland developed an interactive computer program called Sketchpad which was the first to use a Graphical User Interface. The user could draw directly into the screen using a pen like device called light pen.

In 1968, Ivan Sutherland along with his student Bob Sproull demonstrated a system that is believed to be the first head mounted display system with three-dimensional tracking capabilities called Sword of Damocles. The setup consisted of stereoscopic display system displaying an output from a computer program which updated itself according to the movements of the user.

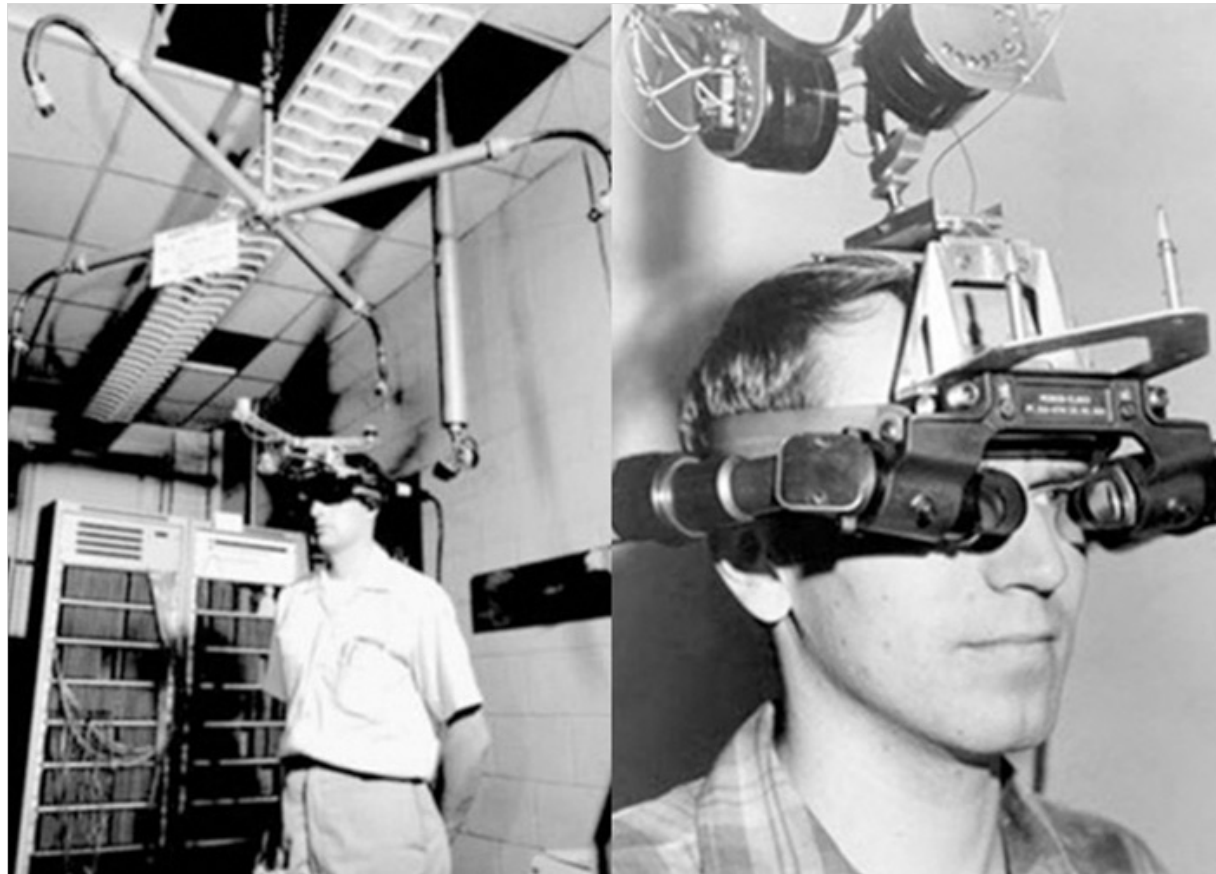


Fig 1. Ivan Sutherland's first VR Head Mounted Display, The Sword of Damocles
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<https://www.dsource.in/course/virtual-reality-introduction/evolution-vr/leep-display>

LEEP Display

In 1979, Eric Howlett developed LEEP (Large Expanse Extra Perspective), a stereoscopic display in a smaller form factor which could deliver an extreme wide angle viewing experience. LEEP remained the basis of technical influence for the later developed VR displays by organizations like NASA and VPL.



Fig 1. LEEP Demonstration

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Visual Programming Lab Research (VPL)

Visual Programming Lab was founded by Jaron Lanier in 1984 to develop programs and products related to VR technology. The vision of the company was manifested in the form of products like Data Glove and EyePhone HMD. Jaron Lanier is believed to be the visionary who coined and popularized the term “Virtual Reality” through the media, creating awareness among the masses.



Fig 1. Data Glove by VPL

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Fig 2. Demonstration of Eyephone HMD by VPL

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Virtuality Gaming System

Addressing the increasing popularity of VR among the common people, the British company W Industries developed a community space VR gaming system called Virtuality in 1991. The multiplayer setup consisted of real time stereoscopic renderings viewed through a head mounted display with handheld joysticks.



Head 4 Head Leisure System used in larger arcades, bowling alleys and theme parks around the world



Legend Quest, a dungeons and dragons game, winner of Cyberedge Journal's Virtual Reality software of the year award 1993



Example of Virtual Reality centres now in over 20 countries



Virtual Reality in a restaurant in Covent Garden UK



Members of the software design department



Touch glove which allows users to feel Virtual Reality objects

Fig 1. An Advertisement for Virtuality

Image Source

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Cave Automatic Virtual Environment

In 1992, the CAVE system was demonstrated as an immersive VR environment which was based on the principle of wrapping up the entire field of view of the user with stereoscopic images forming a virtual cave around. The users equipped with stereoscopic glasses could submerge themselves in the visual representations, projected to the walls of the cave which were updated to align with his/her perspective. CAVE system was developed by Carolina Cruz-Neira, at the University of Illinois, Chicago Electronic Visualization Laboratory.



Fig 1. CAVE System
Image Source

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SEGA VR Goggles

Sega launched its VR headset dubbed as Sega VR in 1993 advertised as the future of gaming with the added dimension of immersivity. The device incorporated cutting edge technologies like LCD screens for vision, head movement tracking, and stereo headphones to provide an immersive gaming experience. However, the product failed to gain popularity among the users because of the ergonomic issues.



Fig 1. Sega VR Headset

Image Source

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Nintendo Virtual Boy

The Virtual Boy, a portable gaming console was launched by Nintendo in 1995. It was marketed as the first gaming system capable of displaying stereoscopic graphics. The display of the Virtual Boy was based on red LED eyepiece reflexive technology which made it monochrome. The controller which came along allowed the users to interact with the graphical world. However, the innovation didn't pay off well for the developers as it ended up as one of the lowest selling products of Nintendo. The lack of colours in the display and the ergonomic issues with the optics pulled back the customers from this unique adventure.



Fig 1. Nintendo Virtual Boy

Image Source

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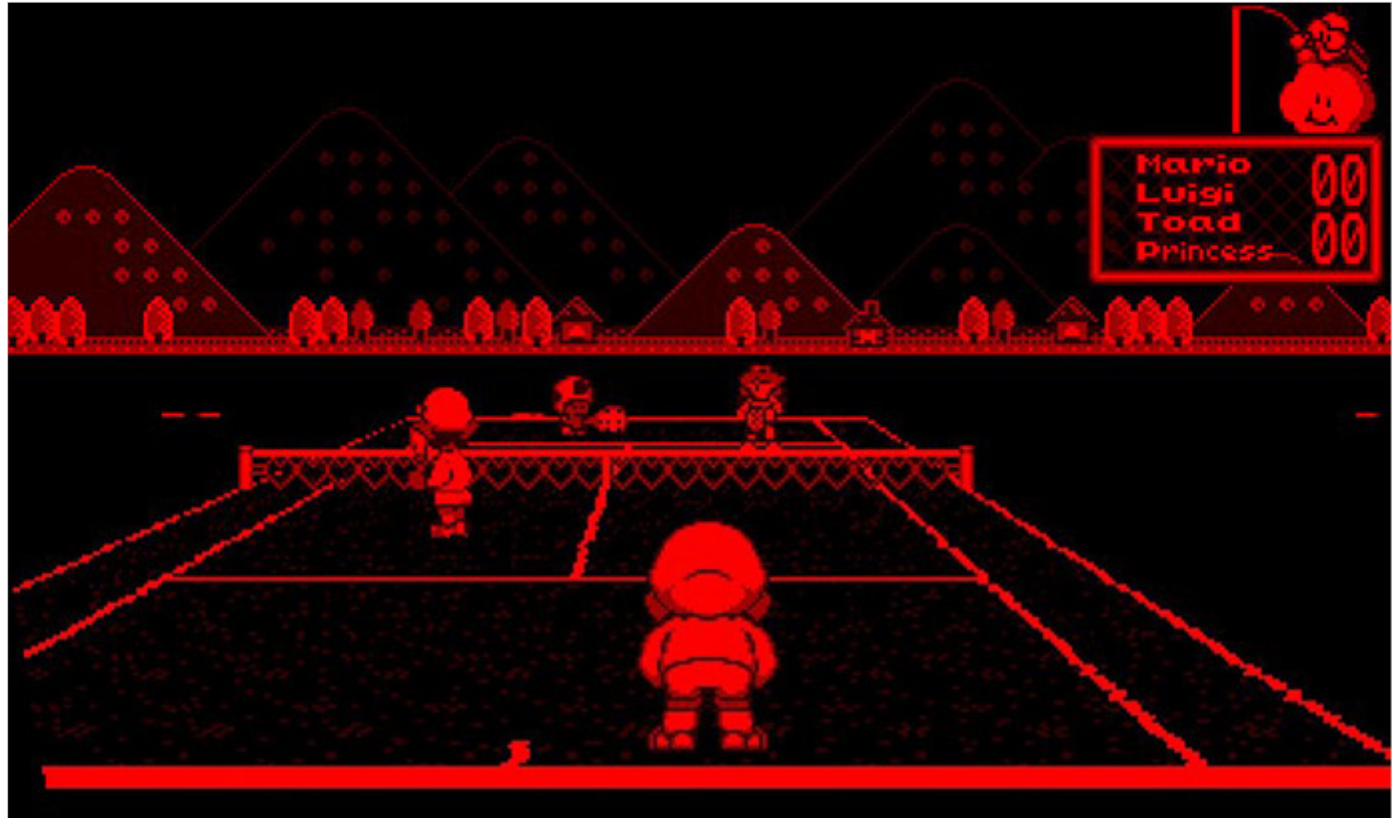


Fig 2. Display of Virtual Boy

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Oculus Rift

Oculus Rift which revolutionized the VR head mounted display was launched as a Kickstarter crowdfunding campaign by Palmer Luckey after the formulation of his company Oculus VR in 2012. The first developer kit launched after a year envisioned a consumer level head mounted display that was way ahead of its predecessors with better ergonomics and build. The latest versions of Oculus Rift are equipped with precise head position tracking capabilities and better controller accessories.



Fig 1. Oculus Rift Developer Kit 1

Image Source

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Fig 2. Oculus Rift 2017

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Google Cardboard

Google Cardboard is a platform developed by Google engineers David Coz and Damien Henry as a low cost solution for experiencing VR content. The basic housing of the device is a cardboard cutout which incorporates a couple of lenses and a slot for attaching a mobile phone. The lens components enables stereoscopic view of the visual content displayed on the phone. The users were encouraged to make their own cardboard viewers with the instructions provided by the developer. The much grounded innovation from Google which was launched in 2014, paved way for the development of similar head mounted displays which made use of a mobile phone to render images.



*Fig 1. Google Cardboard
Image Source*

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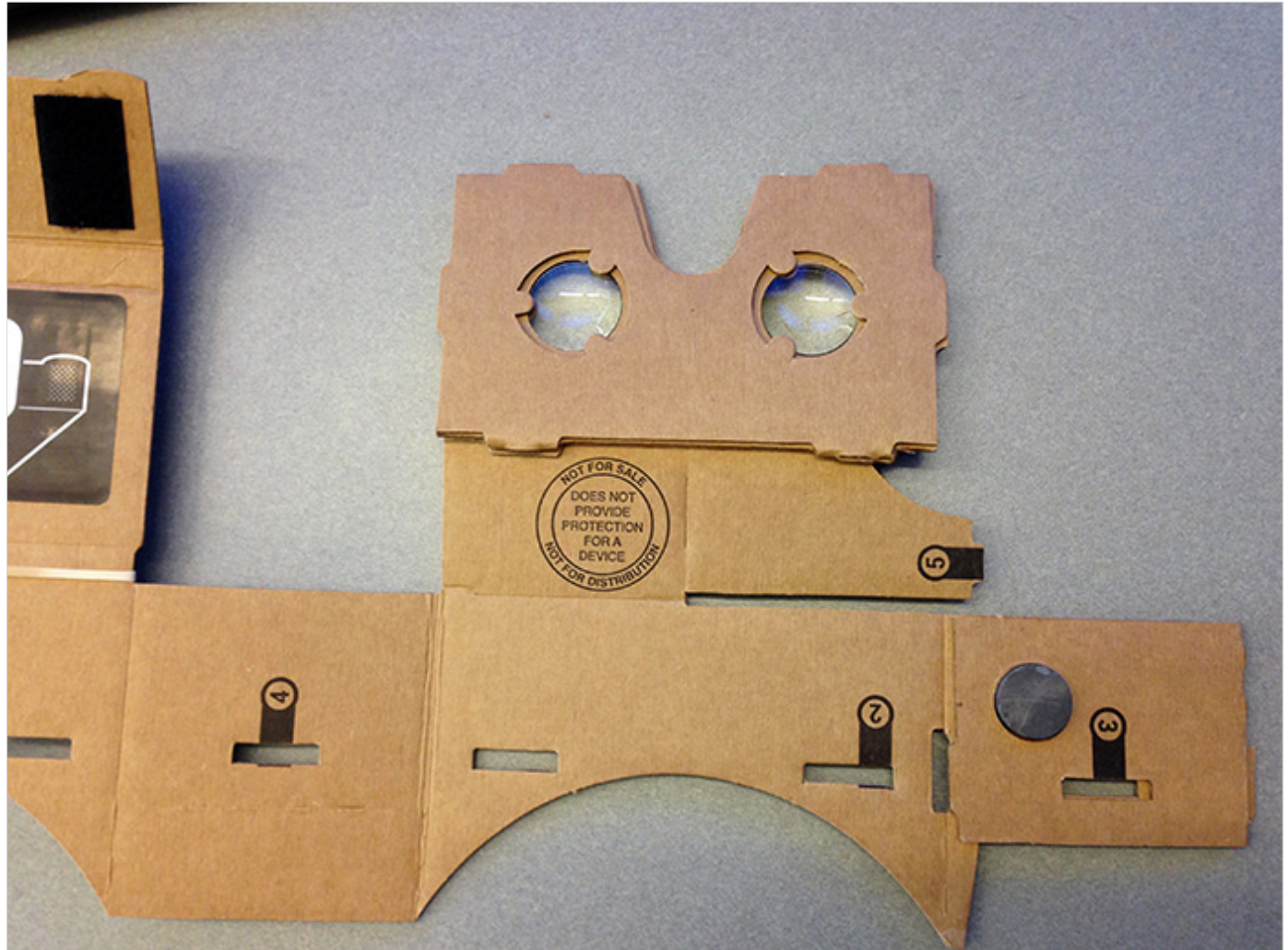


Fig 2. Google Cardboard fully unfolded

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HTC Vive

HTC Vive is a room scale device setup developed by the collaborative efforts of HTC and Valve Corporation. The Vive package consists of a head mounted device with a high resolution stereoscopic display, base stations which incorporate infrared light emissions for precise position tracking and controllers with embedded sensors for physical interactions. The display requires a computer with a powerful Graphical Processing Unit to render the visual representations of the constantly updated virtual world. The device was officially launched by HTC in February 2015.



*Fig 1. HTC Vive
Image Source*

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360 Video

The efforts to capture or record the entire field of view of the space around resulted in obtaining spherical videos of which the field of view can be controlled by the user during the time of playback. The technology of widescreen cinematic views like that of Cinerama can be considered as the forerunners of 360 degree videos where multiple cameras were used to record content simultaneously. 360 degree videos are recorded using a rig made of multiple cameras facing each direction and then stitching together the individual videos into a single one. The multiple camera rigs are now replaced by single camera units which are equipped with multiple lenses facing each direction.



Fig 1. GoPro Omni 360 Monoscopic Multiple Camera Rig

Image Source

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Fig 2. Ricoh Theta 360 Monoscopic Camera

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Standalone VR Headsets

An underlying commonality of both HTC Vive and Oculus Rift is the inevitable dependency on a computer to render images for it. Although these devices have gained popularity among the developers and VR enthusiasts, the high pricing and conditional portability pull them back from being consumer friendly. Catering to these issues, both HTC and Oculus are coming up with standalone Head mounted displays which rather depend on an inbuilt processing unit to render the virtual world. These devices have the advantages of being untethered or unbound to other hardware components in the system which gives the user more freedom of movement.



Fig 1. Oculus Go

Image Source

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*Fig 2. HTC Vive Focus
Image Source*

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VR and Prospects

Engineers, designers and developers all around the globe continue the efforts to manifest the immense potential of virtual reality technology catering to various possibilities. The boundaries which distinguish virtual reality from related technologies like augmented reality are diminishing, leading to the emphasis on a broader canvas of mixed reality technology. Leading tech-companies like Microsoft, Google and Apple are developing augmented reality systems and software applications which are readily available for public consumption. Microsoft developed Hololens, a head mounted device which can augment 3D content on our surrounding real world view. Startup ventures like Magic Leap and Avegant are currently working on devices which use light field technology for experiencing mixed reality applications.



Fig 1. Microsoft Hololens

Image Source

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Applications of VR

VR provides an intuitive way of human computer interaction where the user can involve and interact with the simulated reality in the same way he/she behaves with the real world. The applications of VR stretch over multi-disciplinary fields and sectors of Design, Architecture, Tourism, Entertainment etc.

1. Design and Architectural Visualization

A huge amount of gathered information is associated with any kind of research and study methodologies. The primitive goal of data visualization techniques is to develop some visual representations out of these in order to make them perceptible and easily accessible to the users.

VR can be used as an intuitive medium to where the users can assess the information and interact to the visualizations. The feeling of physical presence and sense of space makes VR effective in experiencing architectural walkthroughs and virtual tourism. Modelling of three-dimensional objects in real time is another application of VR systems.

2. Medical Applications

VR can be used for the treatment of patients with mental disorders of phobia. The users are allowed to confront their fears in a controlled environment which is otherwise impractical to achieve in a real scenario. It is also used as a meditation technique for overcoming stress and anxiety. Intuitive, alternative therapies based on VR are nowadays used for mental and physical [rehabilitation](#) [5].

3. Training and Simulation

Industries like aviation and mining require effective methodologies to practically train their professionals for getting acquainted with the technicalities involved. The high stakes of risk and capital involved make these mock training exercises inevitable. First such applications of VR were explored in the form of flight simulators which helped the pilots to overcome practical difficulties. VR systems are nowadays used for training of surgeons, mining workers, soldiers etc.

4. Tele Operation

Tele Operation is the technology which allows conducting remote operations without being physically present in the actual space. VR can be used to achieve possibilities of teleoperation where the user can carry out operations remotely from a controlled space using a remote control system. VR seems to be the only effective solution when the distant environment is hazardous to human life or impractical to work (Remote bomb diffusion, Remote astronomic [explorations](#)) [6].

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5. Entertainment

Entertainment is the domain which effectively brought VR to the masses. The added dimension of immersion achieved through VR games makes the collaboration tailored for the purpose of entertainment. Storytelling in VR is being explored in the form of 360 videos which is now gaining popularity.

6. Education

Education is another domain which can make use of VR technology to enhance the effectiveness of teaching and learning. Virtual environments can be a better way of representation of information to the students as they provide the possibility of understanding through interaction. Virtual field trips (museums, historic sites), Simulation based training (Medical students) are some of the methodologies that are being implemented today. VR can also be used for education sector catering to those with special needs.

7. Performing Arts

VR redefines the possibilities of performance based artists by adding attributes of interactivity. Wearable accessories are effectively used by the artists to enhance the experience delivered through simulations which interact with them in the desired manner.

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Resources

Web Links:

- Virtual Reality - Historical Overview - Cave, Research, Experience, and Computer
<http://science.jrank.org/pages/11561/Virtual-Reality-Historical-Overview.html>
- The sights and scents of the Sensorama Simulator
<https://www.engadget.com/2014/02/16/morton-heiligs-sensorama-simulator/>
- Virtual Realities Then and Now: The Caves of Lascaux
<http://www.transparencynow.com/lascaux.htm>
- Virtual and Augmented Realities: Asking the right questions and traveling the path ahead
<https://medium.com/@claybavor/virtual-and-augmented-realities-asking-the-right-questions-and-traveling-the-path-ahead-2428b9d13c01>
- Forgotten genius: the man who made a working VR machine in 1957: A Gear VR from the 1950s?
<http://www.techradar.com/news/wearables/forgotten-genius-the-man-who-made-a-working-vr-machine-in-1957-1318253/2>
- Unraveling The Enigma Of Nintendo's Virtual Boy
<https://www.fastcompany.com/3050016/unraveling-the-enigma-of-nintendos-virtual-boy-20-years-later>
- Nolan Bushnell with VPL EyePhone and Larry Wall Nomadic Research Labs
<https://microship.com/nolan-bushnell-vpl-eyephone-larry-wall-1988/>
- A Brief History of Oculus
<https://techcrunch.com/2014/03/26/a-brief-history-of-oculus/>

Original Video Source:

- Sega VR Demonstration
www.youtube.com/watch?v=yd98RGxad0U
- History of VR (Cnet)
www.youtube.com/watch?v=hDWfsIbBtwE

1. What is Virtual Reality?
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Virtual Reality: Introduction

An Introduction to Virtual Reality

by

Azif Ismail with Prof. Jayesh S. Pillai

IDC, IIT Bombay

Source:

<https://www.dsource.in/course/virtual-reality-introduction/resources>

- The Arrival of a Train at La Ciotat Station
www.youtube.com/watch?v=b9MoAQJFn_8

- Morton Heilig's Sensorama Interview
www.youtube.com/watch?v=vSINEBZNCKs

- The Sword of Damocles
www.youtube.com/watch?v=ISJWZpFIAIQ

- Ivan Sutherland: Sketchpad Demo
www.youtube.com/watch?v=USyoT_Ha_bA

Videos Links:

- Sega VR Demonstration



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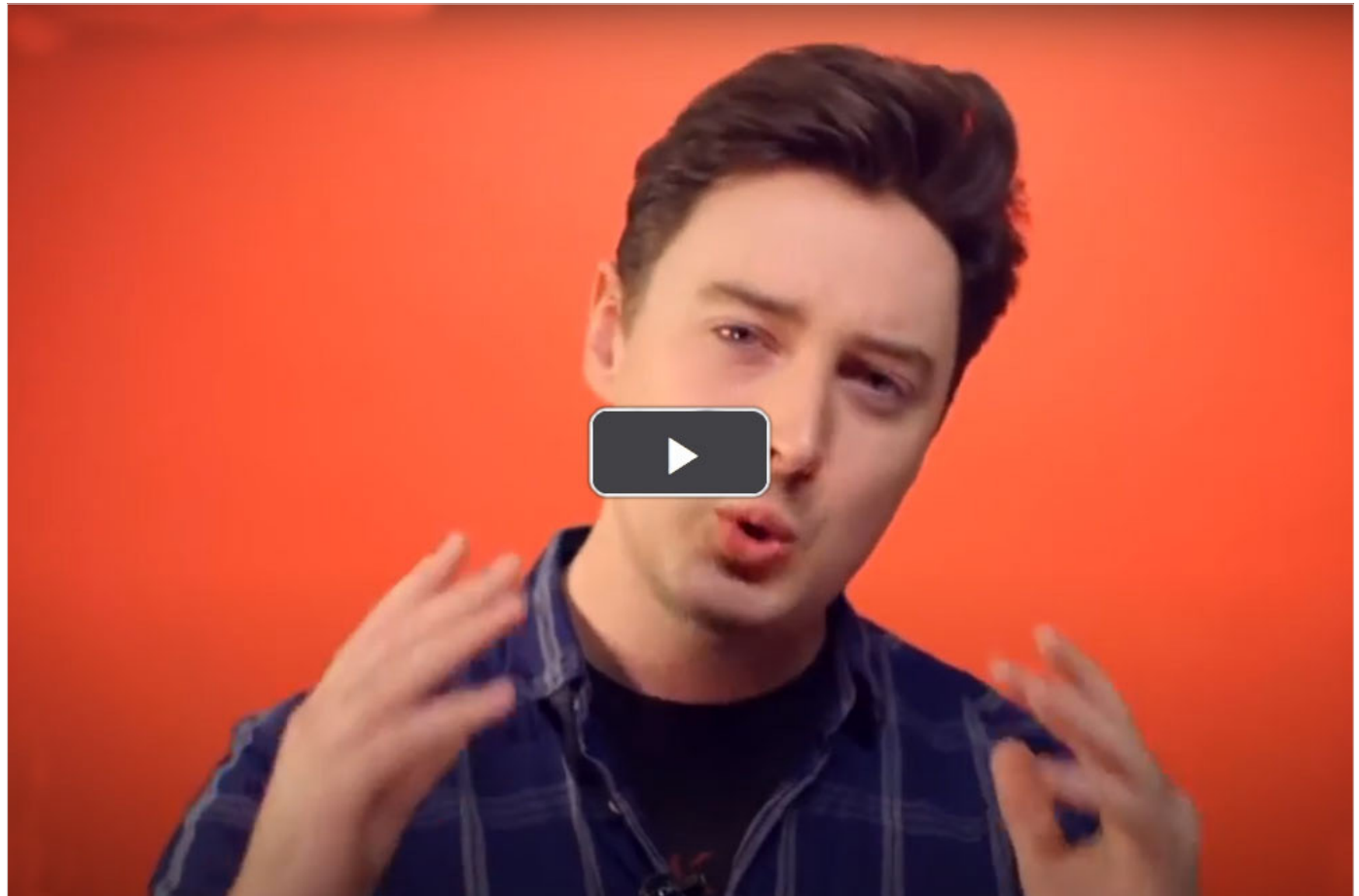
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L'arrivée d'un train à La Ciotat (1895) - frères Lumière



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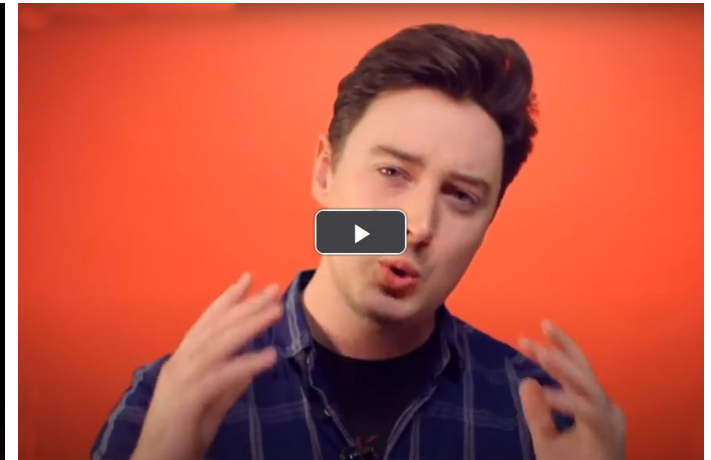
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Video



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History of VR



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Ivan Sutherland - Sketchpad Demo

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Contact Details

This documentation was done by Azif Ismail at IDC, IIT Bombay.

You can get in touch with him at [azifismail91\[at\]gmail.com](mailto:azifismail91[at]gmail.com)

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